ADVANCED AUTOMOTIVE PISTON ENGINES - MANUFACTURING, EFFICIENCY AND EMISSIONS R&D

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The Idaho National Engineering Laboratory (INEL) is working with the Low Emissions Partnership of the U.S. Council for Automotive Research (USCAR) on four projects in their Engine Support System Technology (ESST) Program supported by the Office of Advanced Automotive Technologies in the DOE Office of Transportation Technologies. These projects are focused on developing manufacturing technologies that will lead to increased reliability, timeliness, and cost and energy efficiency for the automotive industry. These projects are also being performed under Cooperative Research and Development Agreements (CRADAs) with the Low Emissions Partnership and are presented here in summary form.

Advanced Manufacturing, Part Integrity - Bore Spray Diagnostics - Advanced Manufacturing is Project #3 in the ESST Program; it is a three-year project, and the CRADA was signed in February, 1995. The project consists of four separate tasks, and various DOE National Laboratories are working with the LEP on these tasks. Work on the Part Integrity-Bore Spray Diagnostics task began in June, 1995, by the INEL and Sandia National Laboratory. Several approaches have been explored for building aluminum engine with acceptable service lifetimes. These have included iron or ceramic sleeve inserts that are cast or pressed into the aluminum block, special high-silicon aluminum alloys, and electroplating the cylinder walls with wear-resistant coating materials. This project examines the use of thermal spray coatings with the specific objective of developing Nondestructive Evaluation (NDE) technology to characterize critical properties of thermal spray coatings on cylinder bores in aluminum engine blocks. These critical properties include bond integrity of coatings to the aluminum substrate, microstructure and coating soundness (e.g., porosity), and coating thickness uniformity.

Key accomplishments to date include the evaluation of six different NDE techniques for measuring the thickness and uniformity of sprayed coatings during the past year. The industry partners then selected two NDE techniques for evaluation in a production environment. A prototype system has been designed and is now under construction at the INEL. It will be delivered to the industry partners during the coming year. The ultimate objective is to apply real-time NDE process control to the thermal spray process that will facilitate the economic mass production of aluminum engine blocks with wear-resistant cylinder walls throughout the automotive industry.

Intelligent Welding of Thin Metal Sections - Intelligent Welding of Thin Metal Sections is part of Project #4 in the ESST Program. It started as a three-year project, and the CRADA was originally signed in January, 1994; the CRADA has subsequently been modified to include participation by the Y-12 Plant at Oak Ridge National Laboratory and extended for two years. The objective of the project is to develop a set of process and weld diagnostic tools to quantify the impact of variations in material and process on weld quality. The approach is to apply recent advances in the intelligent control of welding processes to plant floor operations in order to reduce scrap, increase product reliability, allow an easier transition to more advanced lightweight materials, and improve productivity and efficiency. The work is presently focused on the precompetitive development of two tools. One is a portable diagnostic system. The purpose of the diagnostic system is to: 1) Monitor the welding process, 2) Obtain information from electrical and vision sensors, 3) Interpret the information in the signals, 4) Provide an analysis of the welding process, and 5) Provide the operator with suggestions for changing the process. The second tool is a process model that incorporates a graphical user interface that supports weld procedure development. Both tools are based on a fundamental understanding of heat and mass transfer from the welding process to the weldment, and the associated information that is found in sensor data.

Key accomplishments to date include synchronizing weld vision video and electrical signal data acquisition in both a laboratory and plant floor environment. The design of a modular computer-based portable diagnostic system was then established and prototype hardware was packaged for plant floor evaluation. Two prototype, real-time process diagnostic systems have been delivered for in-plant evaluation of gas tungsten arc welding. They provide a rapid, non-intrusive means of determining the condition of the welding equipment, the state of the welding process being analyzed, and guidance for correcting identified problems. Utilization of the diagnostic systems has resulted in improved fixture designs and welding practices being implemented on the plant floor. Work during the coming year will be focused on the establishment of a prototype system for gas metal arc welding and the in-plant evaluation of a prototype system. The ultimate goal of implementing real-time welding control appears achievable.

Spray Formed Tooling for Automotive Applications - Spray Formed Tooling for Automotive Applications is Project #6 in the ESST Program. It is a five-year project, and the CRADA was signed in June, 1994. The objective of the project is to develop a cost-effective, commercially viable spray forming process for the rapid production of net-shape molds, dies, and related tooling, and to demonstrate the technology by producing simple and complex-shaped tooling for evaluation by USCAR participants. The approach uses INEL-patented spray forming technology to produce tooling, such as plastic injection molds and stamping dies, by combining rapid solidification processing and net-shape materials processing into a single step. The approach is compatible with rapid prototyping technology, such as stereolithography, selective laser sintering, and laminated object manufacturing. Heat is extracted rapidly in-flight, by convection as the spray jet entrains cool inert gas to produce undercooled and semi-solid droplets. At the pattern, the droplets weld together while replicating the shape and surface features of the pattern. Tool formation is rapid; bench-scale tools have been produced in minutes.

The work began using low melting point alloys, starting with tin and then working up in melting point to zinc- and aluminum-based alloys and finally tool steel. The experimental work has been supplemented with mathematical modeling of the spray forming process. Results have now demonstrated the technical feasibility of spray forming Kirksite (a die alloy used for plastic molding) and aluminum-based prototype tooling for plastic injection molding. Tool pattern shape and surface texture replication were excellent, even with D2 tool steel. "As-sprayed" tooling is near the theoretical density with hardness approximately 20% higher than cast material. Compared to commercial material, spray-formed tooling exhibits a refined, homogenous microstructure for improved wear resistance. Due to rapid solidification of spray formed material, a unique heat treatment process is possible resulting in increased tool hardness with minimal distortion. Construction of a prototype spray forming system for producing low-cost, net-shape tooling is nearing completion.

Development of a New Spark Plug Heat Rating Test Apparatus - The Development of a New Spark Plug Heat Rating Test Apparatus is part of Project #14 in the ESST Program; it is a three-year project. The CRADA was signed in January, 1995, and it also includes the Champion Spark Plug Division of Cooper Industries and the Autolite Division of Allied Signal. The objective of the project is to develop a new spark plug heat rating test apparatus to substitute for and replace the existing LABECO single cylinder internal combustion engine that uses benzene as its fuel. The approach is to develop a non-combustion spark plug heat transfer test apparatus for determining heat rating. Work began with the development of a spark plug heat transfer model in order to predict maximum plug surface temperatures. A first generation non-combustion test apparatus was then constructed, and techniques were developed for measuring plug surface temperature for correlation and validation of the mathematical model. A number of modifications have been made to the first-generation apparatus, and work has now focused on correlating existing plug heat ratings with maximum plug surface temperatures using an infra-red camera. The initial correlations have been excellent, but they must be expanded and validated for all plug families, particularly at high temperatures (up to 1100°C). This issue is now considered the key technical hurdle for this project.